MISSOURI BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody/Assessment Unit (AU): Wyandotte County Lake

Water Quality Impairment: Eutrophication

1. INTRODUCTIONS AND PROBLEM IDENTIFICATION

Subbasin: Independence-Sugar

County: Wyandotte

HUC 8: 10240011

HUC 11 (HUC 14s): 10240011030(030)

Ecoregion: Central Irregular Plains, Osage Cuestas (40b)

Drainage Area: 8.0 square miles (20.7 square kilometers)

Conservation Pool: Surface Area = 401 acres (0.63 square miles, 1.62 square kilometers)
Maximum Depth = 13.0 meters (42.7 feet)
Mean Depth (feet) = 4.1 meters (13.5 feet)
Total Storage Volume = 5432 acre-feet
Retention Time = 2.24 years
Mean Annual Inflow = 5.4 cfs

Designated Uses: Primary Contact Recreation (A), Expected Aquatic Life Use, Food Procurement Use

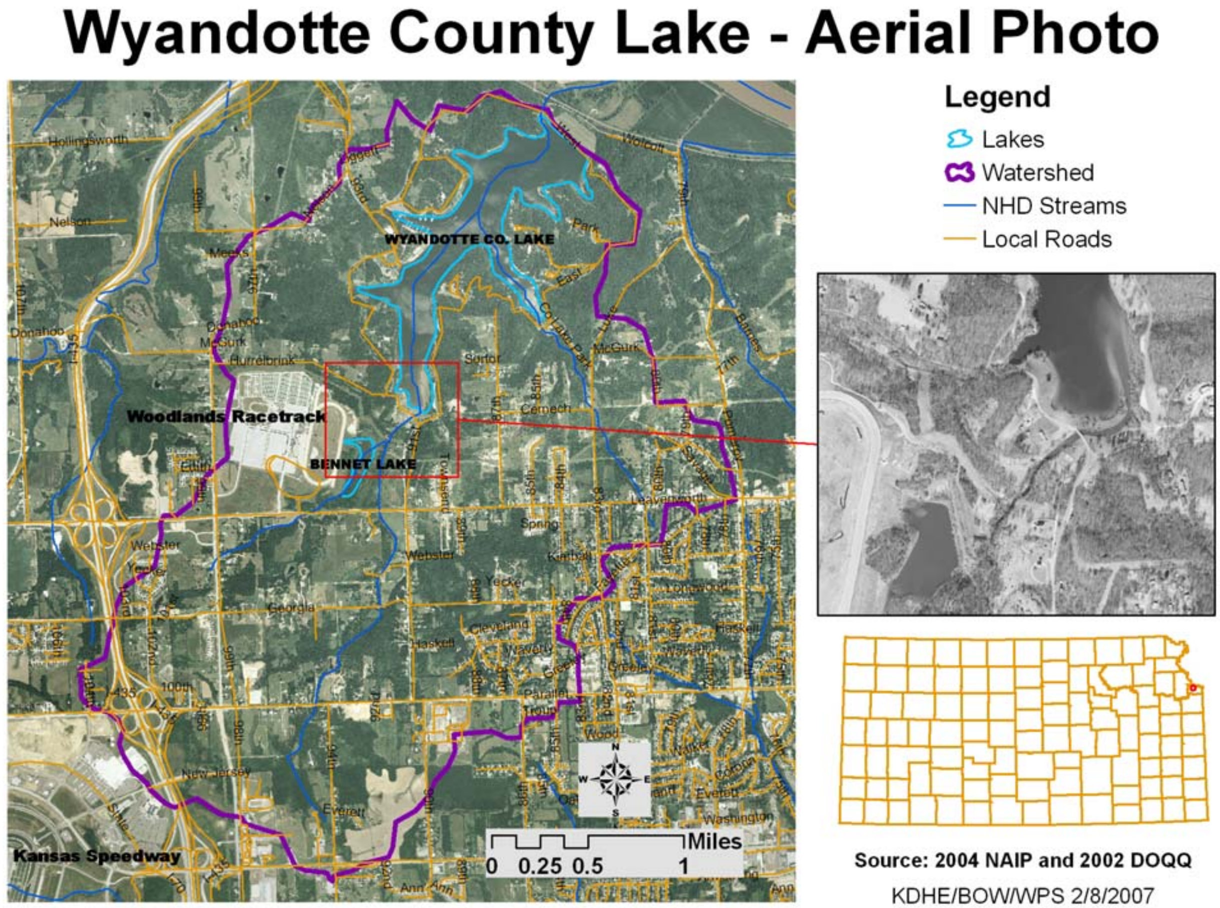
303(d) Listings: 2006 Missouri River Basin

Impaired Use: All uses are impaired to a degree by eutrophication

Water Quality Standard: Nutrients - Narrative: The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the production of undesirable quantities or kinds of aquatic life. (KAR 28-16-28e(c)(2)(B)).

The introduction of plant nutrients into surface waters designated for primary or secondary contact recreational use shall be controlled to prevent the development of objectionable concentrations of algae or algal by-products or nuisance growths of submersed, floating, or emergent aquatic vegetation. (KAR 28-16-28e(c)(7)(A)).

Figure 1. Map of the TMDL Area



2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Eutrophication: Slightly Eutrophic (SE), Trophic State Index (TSI) = 50.9 (average from 1985 to 2004, TSI ranging from 46.6 to 55.2)

The Trophic State Index (TSI) is derived from the chlorophyll *a* concentration (Chl-a). Trophic state assessments of potential algal productivity are made based on Chl-a, nutrient levels, and values of the Carlson Trophic State Index (TSI). Generally, some degree of eutrophic conditions is seen with Chl-a over 12 µg/L and hypereutrophy occurs at levels over 30 µg/L. The Carlson TSI derives from the Chl-a concentrations and scales the trophic state as follows:

1. Oligotrophic TSI < 40
2. Mesotrophic TSI: 40 - 49.99
3. Slightly Eutrophic TSI: 50 - 54.99
4. Fully Eutrophic TSI: 55 - 59.99
5. Very Eutrophic TSI: 60 - 63.99
6. Hypereutrophic TSI: $\geq$ 64

Monitoring Site: KDHE Station LM042401

Table 1. Wyandotte Co. Lake Water Quality Data Summary

Date	Layer	Depth m	DO mg/L	Temp °C	NH3 mgN/L	NO23 mgN/L	NO2 mgN/L	NO3 mgN/L	TKN mg/L	PO4 mg/L	TP mg/L	pH	S_COND us/cm	HARDNESS mg/L	TDS mg/L	TSS mg/L	TURB NTU	TOC mg/L	Chl-a ug/L	SECCHI m
8/12/1985	Epilimnion	0.5	7.8	26	0.02	0.04				*<0.01*	0.02	7.7	500	148		*<1*	4		5.62	
	Hypolimnion	11.5	0	11	0.31	0.22				0.53	0.57	7.4	475	182		4	4			
8/22/1988	Epilimnion	0.5	7.2	29	0.15	*<0.01*					0.03	8.45	411	150	222	3	2		5.1	
	Hypolimnion	14	0.2	11	0.75	*<0.01*					0.14	7.65	452	174	239	16	9			
7/28/1993	Epilimnion	0.5	8.8	29	*<0.05*	0.03			*<0.1*		*<0.05*	8.35	395	140	203	11	5		11.2	1.1
	Hypolimnion	12	0.2	10	0.37	0.09			0.5		0.06	7.55	520	190	273	45	27			
7/21/1997	Epilimnion	0.5	7.5	29	*<0.02*		*<0.05*	*<0.01*	0.187	*<0.02*	0.01	7.58	467	179	252	10	2		6.3	1.9
	Hypolimnion	11	0	11	0.33		*<0.05*	*<0.01*	0.71	*<0.02*	0.04	7.07	495	200	272	10	4.5			
7/25/2001	Epilimnion	0.5	8.3	31	*<0.02*		*<0.05*	*<0.01*	*<0.1*	*<0.02*	0.022	8.06	361	125	195	6	3	6.018	12.3	1.8
	Hypolimnion	14	0.1	12	1.169		*<0.05*	*<0.01*	0.802	*<0.02*	0.245	7.18	461	159	244	7	4.8	6.808		
6/22/2004	Epilimnion	0.5	8.6	24.5	*<0.1*		*<0.05*	*<0.1*	0.736	*<0.25*	0.024	7.7	414	148	230	*<10*	3.02	3.749	10	1.59
	Hypolimnion	12	0.1	15	0.14		*<0.05*	*<0.01*	0.912	*<0.25*	0.082	7.01	451	169	251	10	9.59	3.279		

Period of Record used: 1985 – 2004 (Sampling years: 1985, 1988, 1993, 1997, 2001, 2004)

Hydrologic Conditions: The drainage area for the Wyandotte County Lake is only 8 square miles in size. The surface area of the Lake is about 0.63 square miles. The inflow of water to the Lake is relatively small, and the retention time of the Lake is relatively long. According to the USGS Lake Hydro data, the mean runoff in the watershed is 8.0 inches per year; the mean precipitation in the watershed is 35.1 inches per year; and the mean loss due to evaporation for the Lake is 44.0 inches per year. The calculated mean outflow for the Lake is 2429 acre-feet per year; and the calculated lake retention time is 2.24 year. This calculated retention time is in the top 10 percentile of all the lakes in Kansas.

Current Conditions: The water quality data for the Wyandotte County Lake are summarized in **Table 1**. All of the samples were collected near the dam between June and August. The Lake stratifies during the summer months (see graphs in **Appendix A**). The depths of the epilimnion layer ranged from 2-6 meters on the sampling dates and were greatly influenced by local weather conditions like wind and temperature. This TMDL will focus on the epilimnion layer of the Lake.

The average total nitrogen (TN) and total phosphorus (TP) concentrations are 0.297 mgN/L and 0.022 mg/L, respectively. The chlorophyll-a is averaged at 8.4 ug/L, ranging from 5.1 ug/L in 1988 to 12.3 ug/L in 2001. The average secchi depth is around 1.6 meters (5.2 feet). These average values indicate that the Wyandotte County Lake is overall a good quality lake with good clarity in the water. The main concern for the Lake is the increasing trend of the chlorophyll-a levels and their corresponding Trophic State Indices (**Figures 2 and 3**).

The total cell counts and biovolumes of the algal community in the Lake are very low, although the algal community chiefly comprises cyanobacteria (Blue-green Algae) (**Tables 2 and 3**). An increasing supply of nutrients, especially phosphorus and possibly nitrogen, will often result in higher growth of blue-green algae because they possess certain adaptations that enable them to outcompete true algae[4].

Figure 2. Chlorophyll-a Levels Over the Years

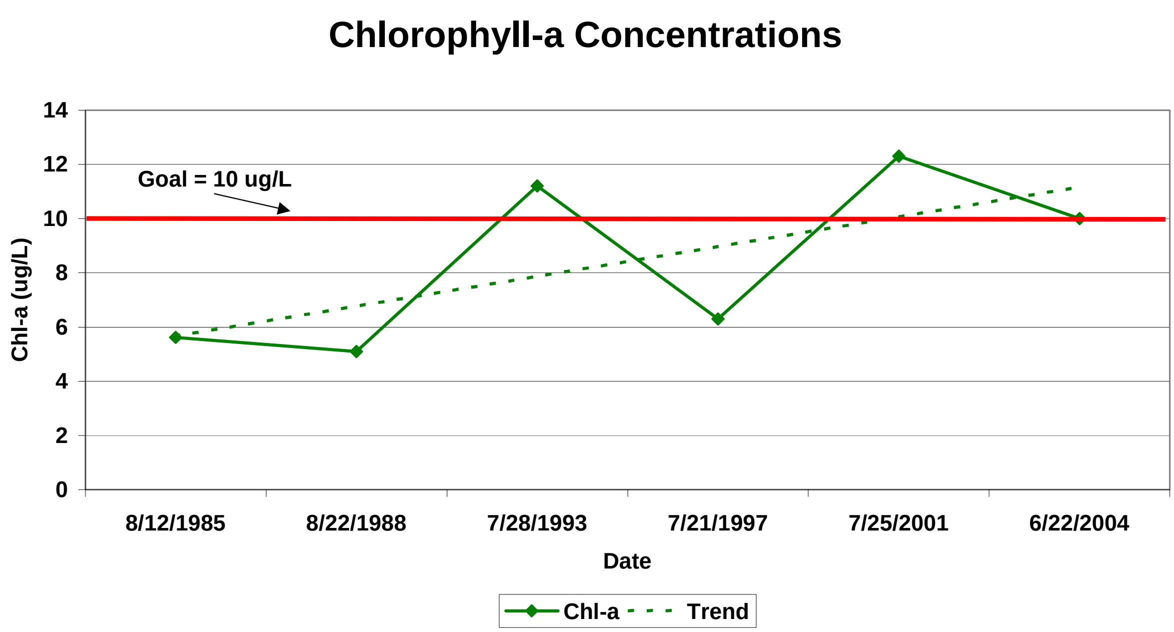


Figure 3. Trophic State Indices Over the Years

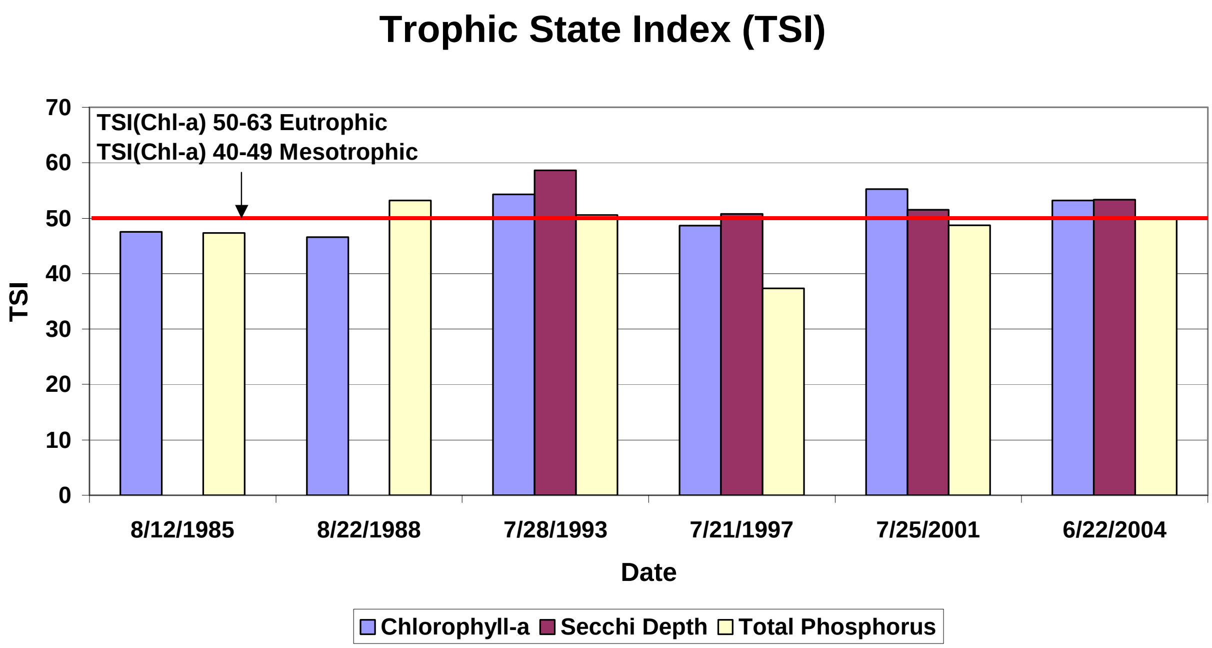


Table 2. Algal Communities Observed in the Lake

Year	Date	Total Count (cells/ml)	Percent Composition				Chl-a (ug/L)
			Green	Blue-Green	Diatom	Other*	
1993	**7/28**	7,180					11.2
1997	**7/21**	4,284	25	67	5	3	6.3
2001	**7/25**	21,263	4	92	2	2	12.3
2004	**6/22**	12,065	14	85	<1	<1	10

* Refers to euglenoids, cryptophytes, dinoflagellates, and other single-celled flagellate groups of Algae.

Source: Lake and Wetland Monitoring Program Report/Summary

Table 3. Algal Biovolumes Calculated for the Lake

Year	Date	Biovolume (mm^3/L)	Percent Composition				Chl-a (ug/L)
			Green	Blue-Green	Diatom	Other*	
1993	**7/28**		15	44	21	20	11.2
1997	**7/21**	2.39	28	5	38	29	6.3
2001	**7/25**	4.919	6	65	14	15	12.3
2004	**6/22**	5.248	6	78	<1	15	10

* Refers to euglenoids, cryptophytes, dinoflagellates, and other single-celled flagellate groups of Algae.

Source: Lake and Wetland Monitoring Program Report/Summary

Table 4. Limiting Factor Determination for the Lake

Year	TN/TP	*Non-algal Turbidity* NAT	*Light Availability in the Mixed Layer* Zmix*NAT	*Partioning of Light Extinction between Algae & Non-algal Turbidity* Chl-a*SD	*Algal Use of Phosphorus Supply* Chl-a/TP	*Light Availability in the Mixed Layer for a Given Surface Light* Zmix/SD	*Shading in Water Column due to Algae and Inorganic Turbidity* Shading	Factors
1993	<11							P=N
1997	18.5	0.38	1.49	11.5	0.61	2.06		P
2001	8	0.25	1.08	21.87	0.61	2.37	5.72	P=N
2004	34.9	0.383	1.551	15.66	0.438	2.549	5.32	P

NAT: non-algal turbidity Chl-a: chlorophyll-a

Zmix: depth of mixed layer SD: secchi depth

Shading - calculated light attenuation coefficient times mean lake depth

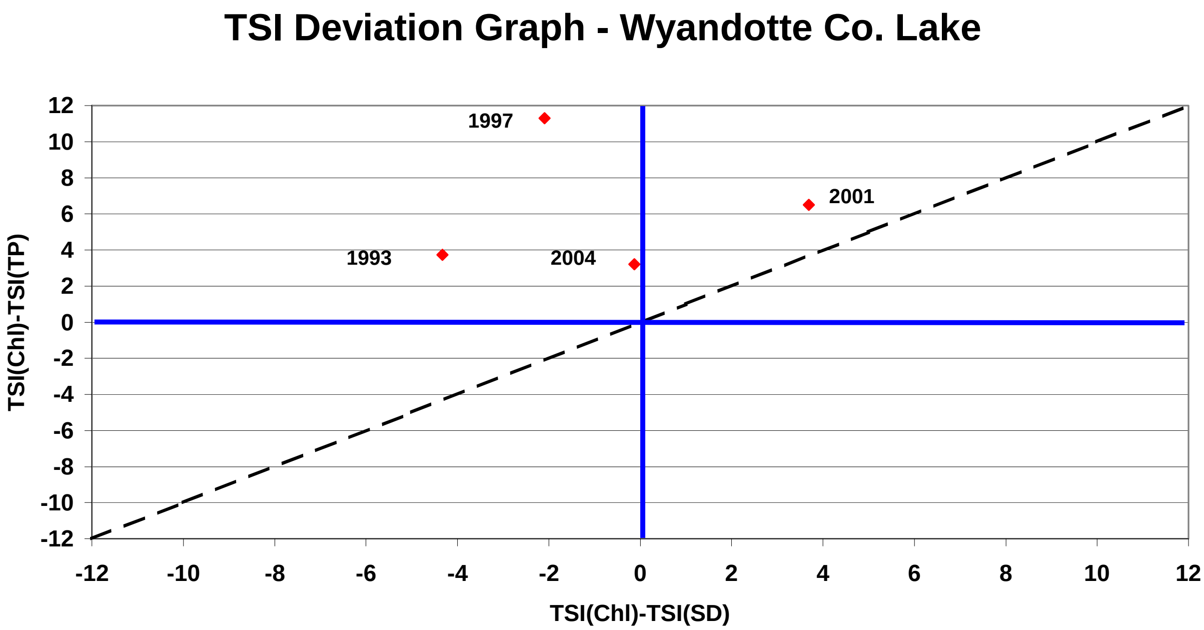
Source: Lake and Wetland Monitoring Program Report/Summary

Table 4 lists seven metrics measuring the roles of light and nutrient in the Lake. Typically, ***TN/TP mass ratios*** above 10-12 indicate increasing phosphorus limitation. ***TN/TP ratios*** of less than 7-10 indicate increasing important of nitrogen. ***Ratios*** of 7-12 indicate that both nutrients, or neither, may limit algal production. ***Non-algal turbidity*** (NAT) values less than 0.4 m^{-1} tend to indicate very low levels of suspended silt and/or clay. ***Light availability*** values in the mixed layer less than 3 indicate abundant light within the mixed layer of a lake and a high potential response by algae to nutrient inputs. Values of ***partitioning of light extinction between algae and non-algal turbidity*** that are greater than 16 indicate that inorganic turbidity is probably not responsible for light extinction in the water column and there is a strong algal response to changes in nutrient levels. Values of ***algal use of phosphorus supply*** that are above 0.4 indicate a strong algal response to changes in phosphorus level. Values of ***light availability in the mixed layer for a given surface light*** that are less than 3 indicate that light availability is high in the mixed zone and the probability of strong algal responses to changes in nutrient levels is high. ***Shading*** values less than 16 indicate that self-shading of algae does not significantly impede productivity and are most applicable to lakes with maximum depths of less than 5 meters. (Source: Lake and Wetland Monitoring Program 2004 Annual Report)

According to the above metrics, the Wyandotte County Lake is likely to be either phosphorus limited or phosphorus and nitrogen co-limited. The Lake also has low levels of inorganic turbidity (silt/clay), high light availability in the mixed layer, and potential high response of algae community to increases in nutrient levels.

Another method for evaluating limiting factors is the TSI deviation metrics (**Figure 5**). Differences of less than 5 units are considered **not** statistically significant different from zero[1]. Values of TSI(Chl-a)-TSI(SD) that are larger than 5 indicate that larger particles (zooplankton, algal colonies) exert more importance for a lake's light regime[1]. Values of TSI(Chl-a)-TSI(SD) that are less than -5 indicate small particle turbidity is important[1]. Values of TSI(Chl-a)-TSI(TP) that are larger than 5 indicate that phosphorus is limiting algal production and biomass[1]. Values of TSI(Chl-a)-TSI(TP) that are less than -5 indicate that phosphorus may not be the limiting factor for algal production and biomass[1]. The TSI deviation chart for the Wyandotte County Lake suggests that the phosphorus might be the limiting factor for algal production in 1997 and 2001. For 1993 and 2004, the chart suggests that the phosphorus may not be the limiting factor, or may not be the single limiting factor. Neither small particles nor large particles dominate in the Lake.

Figure 5. TSI Deviation Chart



Desired Endpoints of Water Quality (Implied Load Capacity) at the Lake, over 2007 – 2015

To prevent further deterioration and reverse the trend in water quality, a goal of 10 µg/L of chlorophyll-a is set for the Wyandotte County Lake. It will ensure long-term protection for the Lake and provide some buffering capacity in case of nutrients overload to the Lake. In support of the chlorophyll-a endpoint, in-lake average concentrations of total phosphorus will need to be at 22 µg/L (ppb) with a maximum level at 27 µg/L (ppb). A corroborating endpoint of average secchi disk depth greater than 1.6 m will also be used to assess the aesthetic quality of the lake for recreation.

Achievement of the endpoints indicates loads are within the loading capacity of the Lake, the water quality standards are attained, and full support of the designated uses of the Lake has been achieved. Seasonal variation has been incorporated in this TMDL since the peaks of algal growth occur in the summer months.

3. SOURCE INVENTORY AND ASSESSMENT

Eutrophication is generally described as the biological response of a lake to elevated nutrients, organic matter, and/or silt [2]. The nutrient loads can come from a variety of sources, including wastewater treatment plant effluent, untreated sewage, urban stormwater runoff, animal waste, pasture runoff, and cropland runoff.

The drainage area or watershed for the Wyandotte County Lake is located within the municipal boundary of Kansas City, Kansas. The watershed is adjacent to a very rapid developing area including the Kansas Speedway and the retail outlets like Cabela's, Nebraska Furniture Mart, and the Legends. The Lake itself is a part of the Wyandotte County Lake Park and surrounded mainly by forest. There are no permitted point sources (NPDES or CAFO) in the watershed.

The land use data show that the watershed underwent a certain degree of urban development from 1992 to 2001 (**Table 5 and Figure 6**). The forest land decreased from 40.8% in 1992 to 32.3% in 2001. The urban developed land increased from 16.9% in 1992 to 20.7% in 2001. The pasture and crop land decreased from 21.1% and 4.9% in 1992 to 12.3% and 2.9% in 2001, respectively. The commercial development is still continuing today at a rapid pace in and around the watershed. Urbanization tends to produce more runoff and higher nutrients and sediment loads to the ecosystem due to the increases of impervious areas in the watershed. Without proper mitigating measures, the watershed and ecosystem will become more polluted and degrade over time. The up-trend in the chlorophyll-a levels in the Wyandotte County Lake is likely a reflection of the initial degradation of the lake ecosystem, as a result of the rapid development. The aerial photos of the Lake show significant amount of sedimentation in the southern end and the eastern arm of the Lake from 1992 to 2002 (**Figures 7 and 8**). Urban stormwater is managed under the Phase I NPDES Permit of the Unified Government of Wyandotte County, Kansas City, Kansas (KS000095656; M-MO25-SO01; expires 9/30/2012).

One of the possible sources for the increasing nutrient inputs to the Lake is the Woodlands Racetrack located at the southwest corner of the Lake. According to a 1991 inspection report of the Racetrack, the domestic sewage and the animal waste from the kennels were discharged into the Kansas City sanitary sewer system, and the dry waste collected from the exercise area for each kennel was picked up and disposed at the Deffenbaugh, Johnson County Landfill. One concern noted in the report was that the potential nitrogen buildup in the soils underlying the exercise areas might create groundwater pollution problems. The KDHE staff determined at the time that a permit was not required for the Woodlands since the facility did not pose a potential for surface water pollution. The stormwater runoff from the facility and the parking lot is of concern to this TMDL since the runoff may contain high levels of sediment and nutrients. The runoff from the Racetrack flows into Bennet Lake located half a mile from the Wyandotte County Lake. Discharge and overflow from the Bennet Lake enter into the streams that flow into the south tip of the Wyandotte County Lake. Soil and water samples around the Racetrack should be tested regularly to determine the degree of contamination from animal waste residues.

Another source of concern is the septic systems still being using in Wyandotte County Lake Park and by some older residential houses on the east side of the Lake. The wild geese population in the park area was very high a few years ago. Since geese-feeding in the park was banned in 2003, the geese population has become under control in the last couple of years. The waste product from the geese might have been a contributing factor to the trophic state in the Lake. Another possible source of nutrients input to the Lake might come from improper waste disposal by private boats on the Lake. It has been observed in some other lakes in Kansas that boat operators sometimes dump their waste tanks into the lake rather than using a pump station. Atmospheric deposition is also a small but constant source of nutrient input to the watershed.

Table 5. Land Use Comparison between 1992 and 2001 in the Watershed

Land Use	1992 (%)	2001 (%)	Percent Changed
Forest	40.8	32.3	**-21%**
Urban/Developed	16.9	20.7	**22%**
Urban Grassland	2	17	**750%**
Pasture/Hay	21.1	12.3	**-42%**
Open Water	8.4	7.1	**-15%**
Grassland/Herbaceous	1.5	6.7	**347%**
Cultivated Crops	4.9	2.9	**-41%**
Other	4.4	1	**-77%**

Source: NLCD 1992, 2001

Figure 6. Land Cover Map

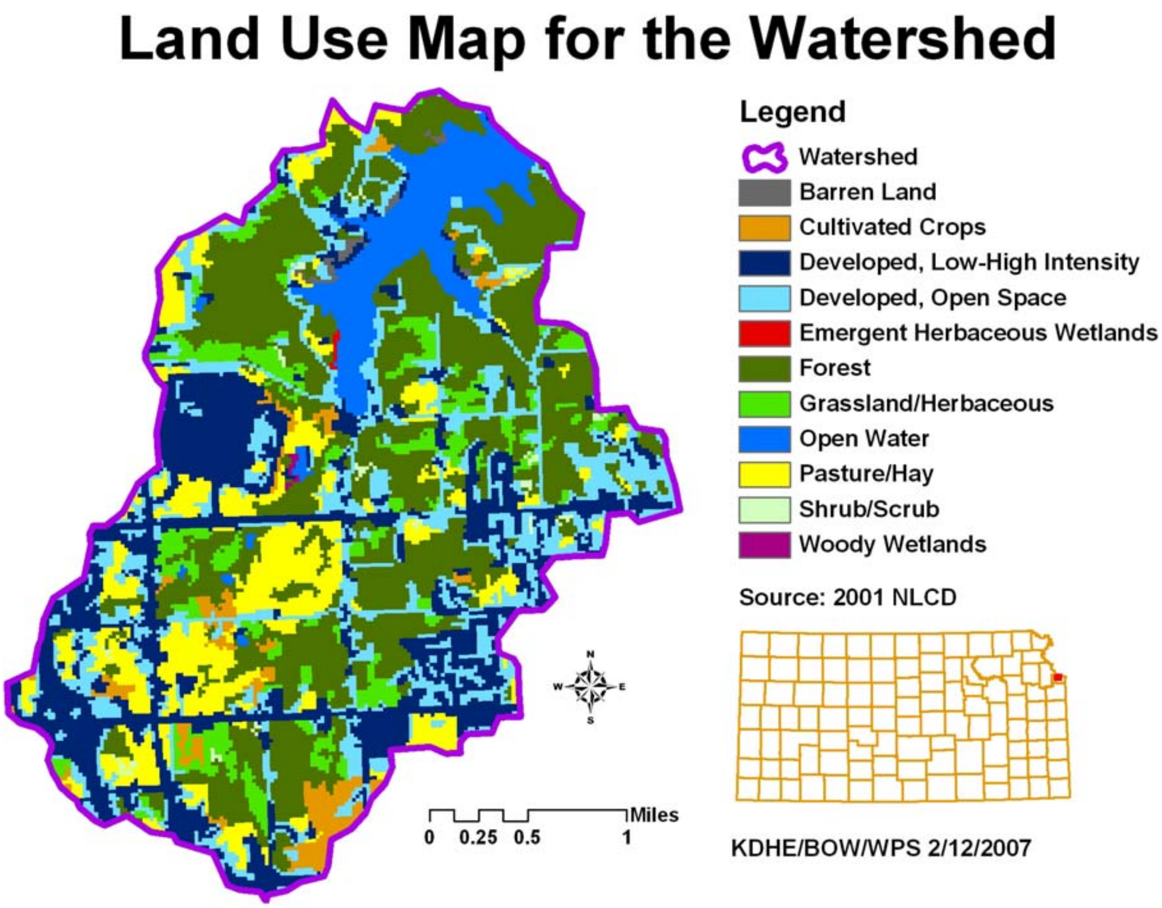


Figure 7. Aerial Photos of the Southern End of the Lake Showing Sedimentation

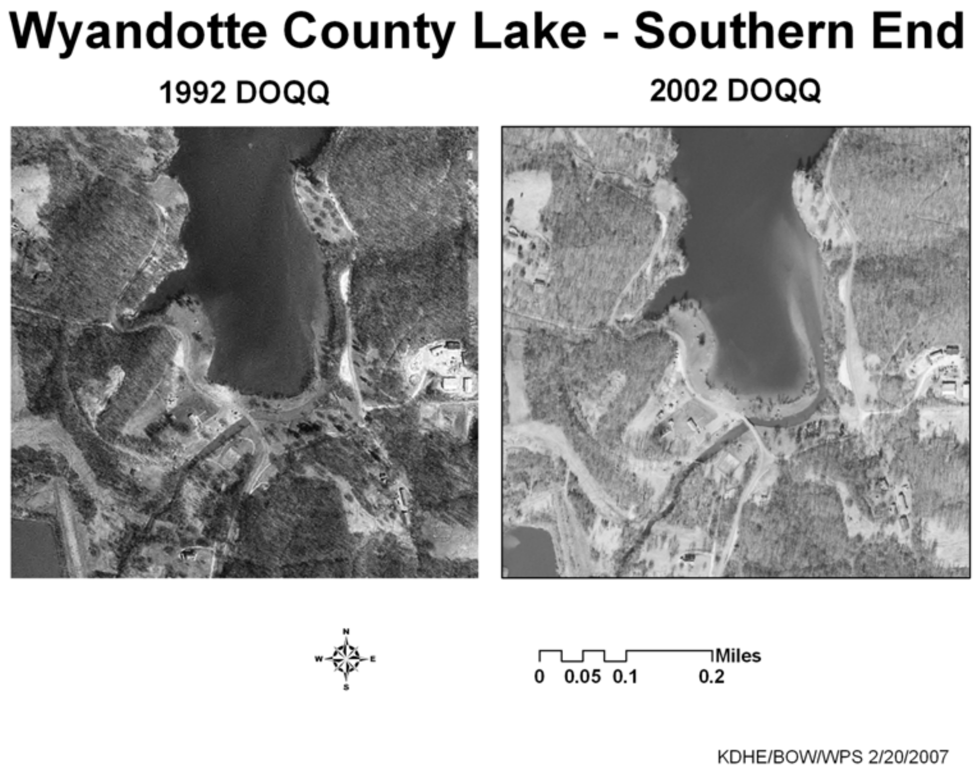
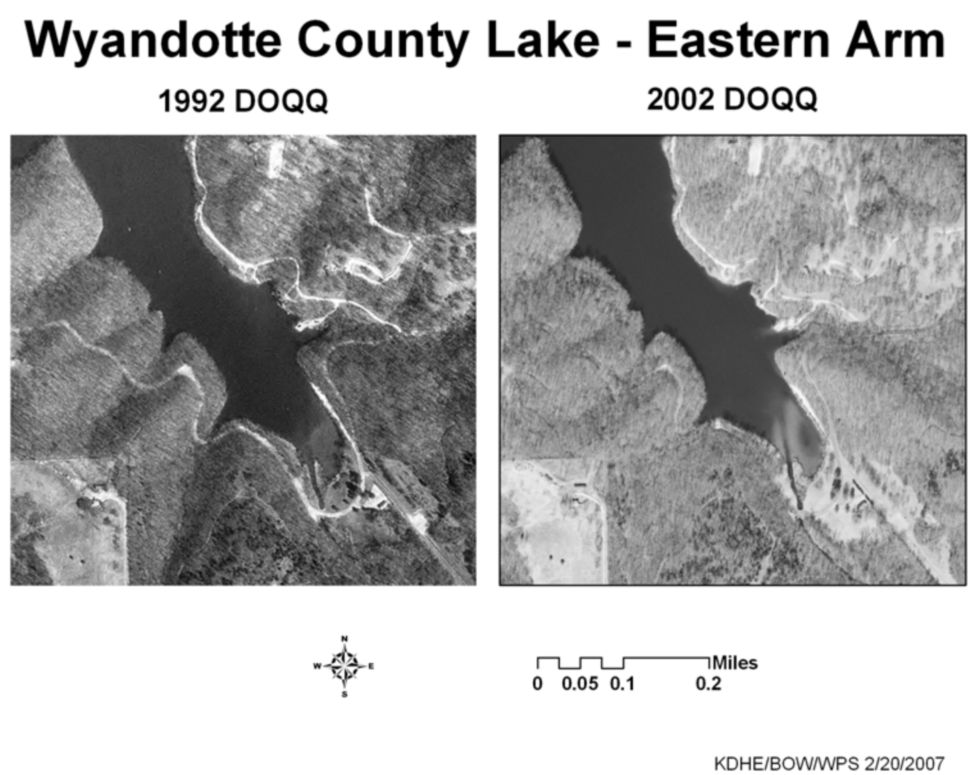


Figure 8. Aerial Photos of the Eastern Arm of the Lake Showing Sedimentation



4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

Point Sources: The Phase I Stormwater permit of the Unified Government of Wyandotte County should direct control practices for developing land in the watershed, including the Woodlands Racetrack. Accordingly, the WLA for stormwater should be 260 pounds of phosphorus per year, reflecting the current and potential proportion of developed land (25%) in the watershed.

Non-point Sources: Non-point sources are the main contributor for the nutrient input and impairment in the Wyandotte County Lake. The likely sources are runoff, leaky septic systems, and animal waste runoff and infiltration through soil and groundwater. The CNET model is used to estimate the current and potential loads of phosphorus to the Lake (**Table 6**). The CNET model summary and explanation sheet are in Appendix B. The maximum daily load calculation is summarized in Appendix C. The estimated atmospheric deposition of total phosphorus is 165 Ibs/year. The Load Allocation for other non-point sources is 75% of the Goal Load or 780 pounds per year, reflecting the proportion of non-urban developed land in the watershed.

Table 6. Load Allocation

Type	Current	Goal	Percent Reduction
TP Waste Load (Ibs/year)	313	260	17%
TP Load (Ibs/year)*	1102	945	14
Atmospheric Deposition	165	165	0%
Other NPS	937	780	17%
Total Loads (Ibs/year)	1415	1205	15%
TP Maximum Daily Waste Load (Ibs/day)	1.63	1.35	17%
TP Maximum Daily Load (Ibs/day)	5.74	4.92	14%
Atmospheric Deposition	0.86	0.86	0%
Other NPS	4.88	4.06	17%
Total Maximum Daily Load (Ibs/day)	7.37	6.27	15%

Defined Margin of Safety: The Margin of Safety is explicitly set. The goal of 10 µg/L chlorophyll-a is more stringent than the target (12 µg/L) normally used by the State in lake eutrophication issues, thus provides a safety buffer for the Lake from uncertainties in loads and water quality management.

State Water Plan Implementation Priority: Since the water quality in the Lake is still in the initial stage of decline, prompt actions by the stakeholders are very likely to stop and reverse the trend. The water quality in the Lake is likely to be restored with moderate efforts. This TMDL will be a High Priority for implementation.

Unified Watershed Assessment Priority Ranking: The watershed lies within the Missouri Basin (HUC 8: part of 10240011) with a priority for restoration work ranking of 25.

Priority HUC 11s and Stream Segments: The whole watershed is located within a single HUC11, no priority sub-watersheds will be identified, but developed land should be the emphasis for Best Management Practices.

5. IMPLEMENTATION

Desired Implementation Activities

1. Continue to collect water quality data for the Lake.
2. Maintain and improve grass buffers and filter-strips along streams and channels in the watershed.
3. Minimize or avoid direct stormwater discharges into waterways or the Lake.
4. Minimize the amount of impervious cover in the watershed to reduce the delivery of pollutants to the Lake.
5. Inspect the septic systems in the park and surrounding residential areas more frequently for potential problems. If feasible, connect the septic systems to a public sewer system to reduce direct nutrients inputs to the Lake.
6. Monitor the animal waste management practices used by the Woodlands Racetrack and require the Racetrack to install measures to reduce runoff and test soil and water samples in the exercise and track areas on a regular basis.
7. If feasible, convert most or all of the remaining cropland to CRP land, and employ Best Management Practices (BMPs) on the cropland to minimize runoff.
8. Utilize State-supported Missouri Basin WRAPS process to reduce loading of nutrients to the Lake.

Implementation Programs Guidance

Watershed Management Program - KDHE

a. Support ongoing implementation projects conducted under the Missouri Basin WRAPS focused on Wyandotte County Lake, including demonstration projects and outreach efforts dealing with erosion and sediment control, stormwater management and practices, pollution prevention, public outreach and studies of water quality impacts of new development.
b. Support septic system inspection, upgrade and repair through the Unified Government of Wyandotte County Environmental Protection Program.
c. Work with the Unified Government to inspect and monitor the animal waste management practices at the Woodlands Racetrack.
d. Provide technical assistance on nutrient management and vegetative buffer development in vicinity of streams.
e. Support aspects of the Unified Government's Stormwater Program, outside the requirements of the Phase I NPDES permit, that promote stream buffers, installation of new and retrofitted stormwater management practices, including Low Impact Development and Best Management Practices, and runoff treatment train practices, all working to mitigate the impacts of impervious area in the watershed.

Stormwater NPDES Permits – KDHE

a. Ensure the Unified Government's Phase I Stormwater Program addresses illicit discharges to the city stormwater system and waterways, public outreach, pollution prevention practices, such as street sweeping, construction site runoff control, post-construction stormwater management, as well as placement of Best Management Practices to address sediment and phosphorus, should Wyandotte County Lake be incorporated in the Phase I area.

b. Ensure industrial and construction stormwater permits are in place to minimize sediment and nutrient loading to the Lake by activities in the watershed.

Water Resource Cost Share Nonpoint Source Pollution Control Program - SCC

a. Apply conservation farming practices, including terraces and waterways, sediment control basins, and constructed wetlands in cropland.
b. Provide sediment control practices to minimize erosion and sediment and nutrient transport from cropland and grassland in the lake watershed.

Riparian Protection Program - SCC

a. Establish or reestablish natural riparian systems, including vegetative filter strips and streambank vegetation along streams.
b. Develop riparian restoration projects.
c. Promote wetland construction to assimilate nutrient loadings.

Buffer Initiative Program - SCC

1. Install vegetative buffer strips along streams.

Timeframe for Implementation: Development of implementation plans should start in 2007. Implementation should occur in 2008-2012.

Targeted Participants: Primary participants for implementation will be the stakeholders in the watershed, the Unified Government of Wyandotte County, and Kansas Department of Health & Environment.

Milestone for 2012: In 2012, sampled data from the Lake should indicate evidence of reduced chlorophyll-at levels relative to those seen in 1991-2005. Should the case of impairment remain, source assessment, allocation and implementation activities will ensue after revisions to the TMDL in 2012.

Delivery Agents: The primary delivery agents for program participation will be Kansas Department of Health & Environment, the Unified Government of Wyandotte County, conservation districts for programs of the State Conservation Commission and the Natural Resources Conservation Service.

Reasonable Assurances:

Authorities: The following authorities may be used to direct activities in the watershed to reduce pollution.

1. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

2. K.S.A. 2-1915 empowers the State Conservation Commission to develop programs to assist the protection, conservation and management of soil and water resources in the state, including riparian areas.

3. K.S.A. 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control non-point source pollution.

4. K.S.A. 82a-901, et seq. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.

5. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan*, including selected Watershed Restoration and Protection Strategies.

6. The *Kansas Water Plan* and the Missouri Basin Plan provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

Funding: The State Water Plan Fund, annually generates $16-18 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the *Kansas Water Plan*. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watersheds and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. Additionally, $2 million has been allocated between the State Water Plan Fund and EPA 319 funds to support implementation of Watershed Restoration and Protection Strategies. This watershed and its TMDL are a High Priority consideration.

Effectiveness: Stormwater control practices, notably those involving runoff retention will reduce pollutant loading to waterways. Nutrient control has been proven effective through conservation tillage, contour farming and use of grass waterways and buffer strips. The key to success will be widespread utilization of stormwater management in developed areas and mitigation measures at sites with high proportions of impervious cover.

6. MONITORING

KDHE will continue its 3-year sampling schedule in order to assess the impairment that drives this TMDL. Based on that sampling, the status of implementation will be evaluated in 2012. Should impairment remain evident, the desired allocations under this TMDL will be refined and more intensive sampling will need to be conducted over the period of 2012-2015 to assess progress in this TMDL's implementation.

7. FEEDBACK

Public Meetings: Public meetings to discuss TMDLs in the Missouri Basin have been held since 2001. An active Internet Web site was established at www.kdheks.gov/tmdl/ to convey information to the public on the general establishment of TMDLs in the Missouri Basin and these specific TMDLs.

Public Hearing: A Public Hearing on these Missouri Basin TMDLs was held in Hiawatha on May 30, 2007.

Basin Advisory Committee: The Missouri Basin Advisory Committee met to discuss these TMDLs on June 26, 2006 in Atchison, December 1, 2006 and January 26, 2007 in Highland, March 16, 2007 in Atchison and May 14, 2007 in Hiawatha.

Milestone Evaluation: In 2012, evaluation will be made as to implementation of management practices to minimize the non-point source runoff contributing to this impairment. Subsequent decisions will be made regarding the implementation approach, priority of allotting resources for implementation and the need for additional or follow up implementation in this watershed at the next TMDL cycle for this basin in 2012.

Consideration for 303d Delisting: The Lake will be evaluated for delisting under Section 303d, based on the monitoring data over the period 2008-2015. Therefore, the decision for delisting will come about in the preparation of the 2016 303d list. Should modifications be made to the applicable water quality criteria during the implementation period, consideration for delisting, desired endpoints of this TMDL and implementation activities may be adjusted accordingly.

Incorporation into Continuing Planning Process, Water Quality Management Plan and the Kansas Water Planning Process: Under the current version of the Continuing Planning Process, the next anticipated revision would come in 2007 which will emphasize revision of the Water Quality Management Plan. At that time, incorporation of this TMDL will be made into both documents. Recommendations of this TMDL will be considered in *Kansas Water Plan* implementation decisions under the State Water Planning Process for Fiscal Years 2008-2015.

Acknowledgement: Special thanks to the Unified Government of Wyandotte County, the KDHE Northeast District Office, and Division of Water Resources, Dept of Agriculture for their help and insights.

Revised 10/18/2007

Bibliography

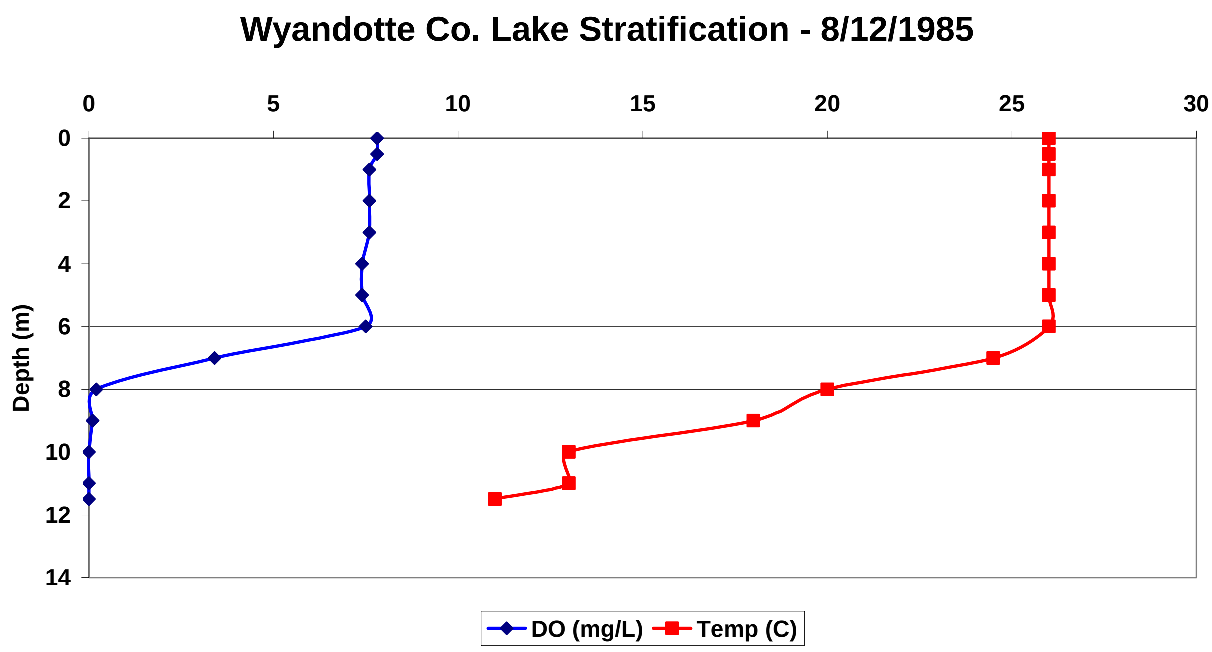
1. Carney, Edward. 1993, 1997, 2001, 2004. Lake and Wetland Monitoring Program Annual Report/Summary. Kansas Dept of Health & Environment.

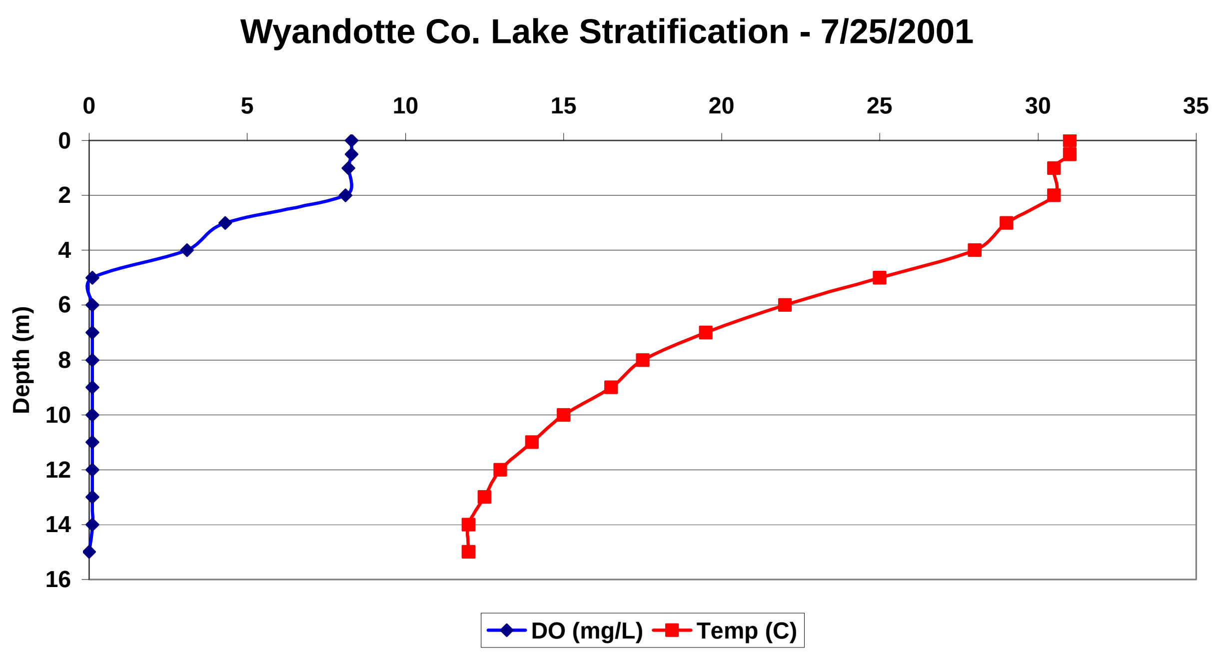
2. Carney, Edward. 1998. A Primer on Lake Eutrophication and Related Pollution Problems. Kansas Dept. of Health & Environment.

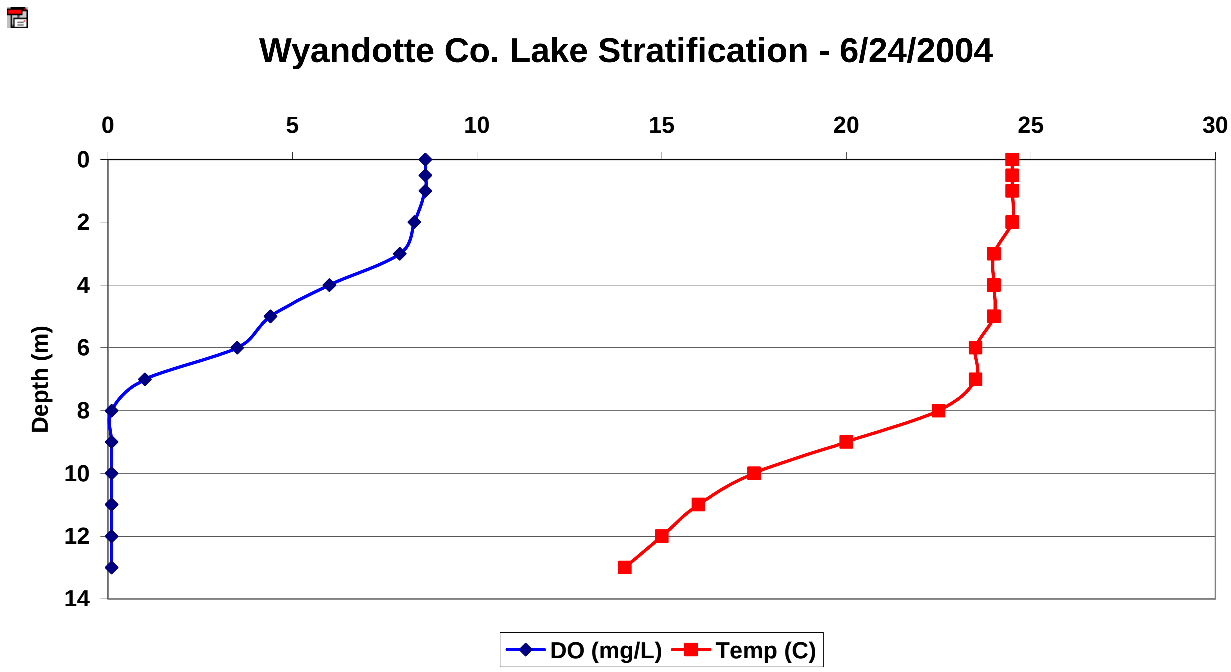
3. U.S. EPA. 1991. Technical Support Document for Water Quality-based Toxics Control (EPA/505/2-90-001). http://www.epa.gov/npdes/pubs/owm0264.pdf

4. The Blue-Green Algae (Cyanobacteria). 2006. Soil and Water Conservation Society of Metro Halifax. http://lakes.chebucto.org/cyano.html

Appendix A. Lake Profiles






Wyandotte Co. Lake Stratification - 6/24/2004
0
5
10
15
20
25
30
Depth (m)
0
2
4
6
8
10
12
14
DO (mg/L)
Temp (C)

Appendix B. CNET Model

The CNET model is a simplified version of the Bathtub model. The CNET model utilizes three and eight empirical models to predict levels of chlorophyll-a (chl-a) and total phosphorus (TP), respectively. These empirical models and their equations are listed in **Tables I-II**. The combination of the first-order settling model and Jones & Bachman model gives the best prediction for the TP and chl-a levels in the Lake. The Jones & Bachman model predicts chl-a levels based on the power of TP. The model works well for the Wyandotte County Lake probably due to the potential strong algal response to phosphorus input that is determined by the Lake's low levels of inorganic turbidity and high light availability in the mixed layer. The first-order settling model outperforms the other models for TP probably due to the fact the Lake is a relatively deep lake with a very long hydrological residence time. The lake depth has a negative impact on the sedimentation rates of phosphorus in the lake and thus resulting higher TP concentrations in the water.

Table I. Chlorophyll-a Options in CNET Model (Source: Bathtub Model Help)

Chlorophyll-a Models			Applicability Constraints			
Option	**Description / Limiting Factors**	**Equations**	**a**	**(N-150)/P**	**Ninorg/Portho**	**Fs**
2	P, Light, Flushing [default]	$Bp = P^{1.37}/4.88$ $G = Zmix\ (0.19 + 0.0042\ Fs)$ $B = K\ Bp\ /\ [(1 + b\ Bp\ G)\ (1 + Ga)]$		>12	>7	
4	P, Linear	$B = K\ 0.28\ P$	<0.9	>12	>7	<25
5	**P, Exponential, Jones & Bachman (1976)**	$\mathbf{B = K\ 0.081\ P^{1.46}}$	**<.4**	**>12**	**>7**	**<25**

See Table III for symbol definitions.

Table II. Chlorophyll-a Options in CNET Model (Source: Bathtub Model Help)

Phosphorus Sedimentation Models

Unit P Net Sedimentation Rate (mg/m^3-year) = CP A1 P^{A2}

Solution for Mixed Segment:

Second-Order Models (A2 = 2):

$$P = [-1 + (1 + 4\ K\ A1\ Pi\ T)^{0.5}] / (2\ K\ A1\ T)$$

First-Order Models (A2 = 1):

$$P = Pi / (1 + K\ A1\ T)$$

Option	Model Description	A1	A2
1	Second-Order, Available P [default] *Inflow Avail P = 0.33 Pi + 1.93 Pio* *See options for specification of available P*	*0.17 Qs/(Qs + 13.3)* *Qs = Max(Z/T,4)*	2
2	Second-Order Decay Rate Function *Fot = Tributary Ortho P / Total P Load* *Requires specification of inflow total & ortho P loads*	*0.056 Fot^{-1}Qs/(Qs + 13.3)* *Qs = Max(Z/T,4)*	2
3	Second-Order	*0.10*	2
4	Canfield & Bachman (1981), Reservoirs	*0.114 $(Wp/V)^{0.589}$*	1
5*	Vollenweider (1976), Northern Lakes	*$T^{-0.5}$*	1
6*	Simple First-Order	*1*	1
7*	**First-Order Settling**	**1 / Z**	**1**
8*	Canfield & Bachman (1981), Natural Lakes	*0.162 $(Wp/V)^{0.458}$*	

See Table III for symbol definitions.

Table III. Definition of Symbols Used in Model Equations

Symbol	Definition
a	Non-Algal Turbidity (m^{-1}) = 1/S - b B , minimum value = 0.08 1/m]
b	Algal Light Extinction Coef = Slope of 1/Secchi vs. Chl-a [default = 0.025 1/m]
As	Surface Area of Segment (km^2)
Ac	Cross-Sectional Area of Segment (km*m)
A1	Intercept of Phosphorus Sedimentation Term
A2	Exponent of Phosphorus Sedimentation Term
B1	Intercept of Nitrogen Sedimentation Term
B2	Exponent of Nitrogen Sedimentation Term
B	Chlorophyll a Concentration (mg/m^3)
Bm	Reservoir Area-Weighted Mean Chlorophyll a Concentration (mg/m^3)
Bp	Phosphorus-Potential Chlorophyll a Concentration (mg/m^3)
Bx	Nutrient-Potential Chlorophyll a Concentration (mg/m^3)
D	Dispersion Rate (km^2/year)
Dn	Numeric Dispersion Rate (km^2/year)
E	Diffusive Exchange Rate between Adjacent Segments (hm^3/year)
Fs	Summer Flushing Rate = (Inflow + Precip -Evaporation)/Volume ($year^{-1}$)
Fin	Tributary Inorganic N Load/Tributary Total N Load
Fot	Tributary Ortho-P Load/Tributary Total P Load
G	Kinetic Factor Used in Chlorophyll a Model
HODv	Near-Dam Hypolimnetic Oxygen Depletion Rate (mg/m^3-day)
K	Calibration Factor (Global Factor x Segment Factor) *
KD	Calibration Factor for Longitudinal Dispersion
L	Segment Length (km)
MODv	Near-Dam Metalimnetic Oxygen Depletion Rate (mg/m^3-day)
N	Reservoir Total Nitrogen Concentration (mg/m^3)
Ni	Inflow Total Nitrogen Concentration (mg/m^3)
Nin	Inflow Inorganic N Concentration (mg/m^3)
Nia	Inflow Available N Concentration (mg/m^3)
Ninorg	Inorganic Nitrogen Concentration (mg/m^3)
Norg	Organic Nitrogen Concentration (mg/m^3)
P	Total Phosphorus Concentration (mg/m^3)
Pi	Inflow Total P Concentration (mg/m^3)
Pio	Inflow Ortho-P Concentration (mg/m^3)
Pia	Inflow Available P Concentration (mg/m^3)
Portho	Ortho-Phosphorus Concentration (mg/m^3)
PC-1	First Principal Component of Trophic Response Measurements
PC-2	Second Principal Component of Trophic Response Measurements
Q	Segment Total Outflow (hm^3/year)
Q_s	Surface Overflow Rate (m/year)
S	Secchi Depth (m)
T	Hydraulic Residence Time (years)
TSIp	Carlson Trophic State Index (Phosphorus)
TSIc	Carlson Trophic State Index (Chlorophyll a)
TSIs	Carlson Trophic State Index (Transparency)
U	Mean Advective Velocity (km/year)
V	Total Volume (hm^3)
W	Mean Segment Width (km)
Wp	Total Phosphorus Loading (kg/year)
Wn	Total Nitrogen Loading (kg/year)
Xpn	Composite Nutrient Concentration (mg/m^3)
Z	Total Depth (m)
Zx	Maximum Total Depth (m)
Zh	Mean Hypolimnetic Depth of Entire Reservoir (m)
Zmix	Mean Depth of Mixed Layer (m)

Table IV. CNET Output:

RESERVOIR EUTROPHICATION MODELING WORKSHEET TITLE -> **Wyandotte County Lake**

Based on CNET.WK1
VERSION 1.0

VARIABLE	UNITS	Current	LC
WATERSHED CHARACTERISTICS...		Latitude	39.2
Drainage Area	km2	20.7	20.7
Precipitation	m/yr	0.89	0.89
Evaporation	m/yr	1.12	1.12
Unit Runoff	m/yr	0.2	0.2
Stream Total P Conc.	ppb	137	114
Stream Ortho P Conc.	ppb	0	0
Atmospheric Total P Load	kg/km2-yr	46	46
Atmospheric Ortho P Load	kg/km2-yr	0	0
POINT SOURCE CHARACTERISTICS...			
Flow	hm3/yr	0	0.0
Total P Conc	ppb	0	0.0
Ortho P Conc	ppb	0	0
RESERVOIR CHARACTERISTICS...			
Surface Area	km2	1.62	1.62
Max Depth	m	13	13
Mean Depth	m	4.1	4.1
Non-Algal Turbidity	1/m	0.25	0.31
Mean Depth of Mixed Layer	m	3.95	3.95
Mean Depth of Hypolimnion	m	1.75	1.75
Observed Phosphorus	ppb	22	22.0
Observed Chl-a	ppb	12.3	10.0
Observed Secchi	meters	1.80	1.80
MODEL PARAMETERS...			
BATHTUB Total P Model Number	(1-8)	7	7
BATHTUB Total P Model Name		SETTLING	
BATHTUB Chl-a Model Number	(2,4,5)	5	5
BATHTUB Chl-a Model Name		JONES	
Beta = 1/S vs. C Slope	m2/mg	0.04517	0.056
P Decay Calibration (normally =1)		1	1
Chlorophyll-a Calib (normally = 1)		1	1
Chla Temporal Coef. of Var.		0.35	0.35
Chla Nuisance Criterion	ppb	12	12
WATER BALANCE...			
Precipitation Flow	hm3/yr	1.44	1.44
NonPoint Flow	hm3/yr	4.14	4.14
Point Flow	hm3/yr	0.00	0.00
Total Inflow	hm3/yr	5.58	5.58
Evaporation	hm3/yr	1.81	1.81
Outflow	hm3/yr	3.77	3.77

VARIABLE	UNITS	Current	LC
AVAILABLE P BALANCE...			
Precipitation Load	kg/yr	37	37
NonPoint Load	kg/yr	130	109
Point Load	kg/yr	0	0
Total Load	kg/yr	168	146
Sedimentation	kg/yr	50	44
Outflow	kg/yr	117	102
PREDICTION SUMMARY...			
P Retention Coefficient	-	0.301	0.301
Mean Phosphorus	ppb	31.1	27.1
Mean Chlorophyll-a	ppb	12.3	10.0
Algal Nuisance Frequency	%	45.5	24.3
Mean Secchi Depth	meters	1.24	1.16
Hypol. Oxygen Depletion A	mg/m2-d	840.4	758.8
Hypol. Oxygen Depletion V	mg/m3-d	480.2	433.6
Organic Nitrogen	ppb	455.4	408.2
Non Ortho Phosphorus	ppb	23.6	21.0
Chl-a x Secchi	mg/m2	15.3	11.6
Principal Component 1	-	2.38	2.31
Principal Component 2	-	0.94	0.85
	Observed	Pred	Target
Carlson TSI P	48.8	53.8	51.8
Carlson TSI Chl-a	55.2	55.2	53.2
Carlson TSI Secchi	51.5	56.9	57.9
OBSERVED / PREDICTED RATIOS...			
Phosphorus		0.71	0.81
Chlorophyll-a		1.00	1.00
Secchi		1.45	1.56
OBSERVED / PREDICTED T-STATISTICS...			
Phosphorus		-1.28	-0.76
Chlorophyll-a		0.01	0.00
Secchi		1.36	1.63

VARIABLE	UNITS	Current	LC
RESPONSE CALCULATIONS...			
Reservoir Volume	hm3	6.642	6.642
Residence Time	yrs	1.7630	1.7630
Overflow Rate	m/yr	2.3	2.3
Total P Availability Factor		1	1
Ortho P Availability Factor		0	0
Inflow Ortho P/Total P		0.000	0.000
Inflow P Conc	ppb	44.5	38.7
P Reaction Rate - Mods 1 & 8		2.0	1.7
P Reaction Rate - Model 2		#DIV/0!	#DIV/0!
P Reaction Rate - Model 3		7.8	6.8
1-Rp Model 1 - Avail P		0.501	0.525
1-Rp Model 2 - Decay Rate		#DIV/0!	#DIV/0!
1-Rp Model 3 - 2nd Order Fixed		0.299	0.316
1-Rp Model 4 - Canfield & Bachman		0.434	0.455
1-Rp Model 5 - Vollenweider 1976		0.430	0.430
1-Rp Model 6 - First Order Decay		0.362	0.362
1-Rp Model 7 - First Order Setting		0.699	0.699
1-Rp Model 8 - 2nd Order Tp Only		0.501	0.525
1-Rp - Used		0.699	0.699
Reservoir P Conc	ppb	31.1	27.1
Gp		0.760	0.760
Bp	ppb	22.8	18.8
Chla vs. P, Turb, Flushing	2	10.7	8.5
Chla vs. P Linear	4	8.7	7.6
Chla vs. P 1.46	5	12.3	10.0
Chla Used	ppb	12.3	10.0
ml - Nuisance Freq Calc.		2.4	2.2
z		0.113	0.697
v		0.396	0.313
w		0.964	0.812
x		0.455	0.243

ORTHO P LOADS...				TOTAL P LOADS... BAF Override (KS)	OrP %		
Precipitation	kg/yr	0	0	0.5	0%	75	75
NonPoint*	kg/yr	0	0	0.23	0%	567	472
Point	kg/yr	0	0	0.8	0%	0	0
Total	kg/yr	0	0			642	546
Total	#/year	0	0			1412	1202

***Nonpoint sources include both stormwater WL and non-point source load.**

Appendix C.

Conversion to Daily Loads as Regulated by EPA Region VII

This TMDL has estimated an annual average load for TP that if achieved should meet the water quality targets. A recent court decision often referred to as Anacostia decision has dictated that TMDL includes a "daily" load (Friends of the Earth, Inc v. EPA, et al.)

Expressing this TMDL in daily load could be misleading in implying a daily response to a daily load. It is important to recognize that the growing season mean chlorophyll *a* is affected by many factors such as: internal lake nutrient loading, water residence time, wind action and the interaction between light penetration, nutrients, sediment loads, and algal response.

To translate long-term averages to maximum daily load values, EPA Region 7 has suggested the approach described in the Technical Support Document for Water Quality Based Toxics Control (EPA/505/2-90-001) (TSD).

Maximum Daily Load = (Long-Term Average Load) * e $^{[Z\sigma - 0.5\sigma^2]}$

where $\sigma^2 = \ln\left(CV^2 + 1\right)$

CV = Coefficient of variation = Standard Deviation/Mean

Z = 2.326 for 99th percentile probability basis

Current TP Waste Load = 313 lbs/yr

Current TP Load = 1102 Ibs/year

Current TP Atmospheric Deposition Load = 165 Ibs/year

Current TP Other NPS Load = 937 lbs/yr

Goal TP Waste Load = 260 Ibs/year
Goal TP Load = 945 Ibs/year

Goal TP Atmospheric Deposition Load = 165 Ibs/year

Goal TP Other NPS Load = 780 lbs/yr

CV = 0.31 (for TP)

e $^{[Z\sigma - 0.5\sigma^2]}$ = 1.9 (99% Multiplier)

Current Maximum Daily TP Waste Load = [(313 lbs/yr)/(365 days/yr)] * 1.9

= 1.63 lbs/day

Current Maximum Daily TP Load = [(1102 lbs/yr)/(365 days/yr)] * 1.9

=5.74 lbs/day

Current Maximum Daily TP Atmospheric Deposition Load = [(165 lbs/yr)/(365 days/yr)] * 1.9 = 0.86 lbs/day

Current Maximum Daily TP Other NPS Load = [(937 lbs/yr)/(365 days/yr)] * 1.9

= 4.88 lbs/day

Goal Maximum Daily TP Waste Load = [(260 lbs/yr)/(365 days/yr)] * 1.9

= 1.35 lbs/day

Goal Maximum Daily TP Load = [(945 lbs/yr)/(365 days/yr)] * 1.9

= 4.92 lbs/day

Goal Maximum Daily TP Atmospheric Deposition Load = [(165 lbs/yr)/(365 days/yr)] * 1.9 = 0.86 lbs/day

Goal Maximum Daily TP Other NPS Load = [(780 lbs/yr)/(365 days/yr)] * 1.9

= 4.06 lbs/day